INTRODUCTION

You have registered for this course to learn a trade. You will, then, recognize the importance of mastering certain basic skills before advancing to more difficult operations.

Provide yourself with a good place to work where you will not be interrupted. Keep your hands, bench and shop area clean. Be careful and thorough with what you do and you will see good results.

BENCH:

It is important that your bench and stool be the correct height and that you have proper light. Benches are available in a variety of sizes, drawers and prices. This will be a matter of personal choice, however, there are a few specifications that must be met for comfort, convenience and speed.

The bench should be 38 inches high and approximately 20 inches wide. The length is a matter of personal choice but should be at least 30 inches. It should have a smooth, flat top surface with a lip around the two sides and back. This lip should extend approximately 3/8 inch above the top surface of the bench. There should be a smooth, half round groove, approximately 3/16 inch deep length-wise of the top about one-half inch from the front edge. The lip and groove will prevent small parts from rolling off the bench. There should be an apron built in the bench high enough to nicely clear your knees and so that it will slide in and out. The apron is approximately 18 inches square and consists of a frame with a light canvas tacked to the bottom. The apron will catch small parts that drop from the bench.

Drawers are convenient to hold the tools. Some should be shallow to make small tools easy to find and to pick up. Others will need to be deeper to hold the larger tools.

STOOL

The stool should be approximately 18 inches high for a person of average height. It will vary in height to fit the individual person. When you are seated in front of your bench in working position with your back fairly straight, the top of your bench should strike you at your arm pits.

LAMP

A gooseneck desk lamp is satisfactory for light. The bulb should be approximately 60 watts. Keep the light low enough so there will be a minimum of glare in your eyes. This type of lamp may be shifted around on the bench to give light for any operation.

After you have learned a few basic skills, you will begin to repair alarm clocks. It is necessary that you gain skill in working with small parts. You should be on the lookout for alarm clocks to repair. These need not be in running condition before you work on them. If your friends and neighbors know that you are taking a Home Study Course, they will probably be glad to give you some of their old clocks for practice material.

Begin work on Lesson 1.

LESSON 1

USE AND CARE OF FILES, PINVISES AND JEWELER'S SAW
ACCURATE FILING OF FLAT SURFACES
INTRODUCTION TO THE SLIDING MILLIMETER GAUGE

The Clock Repairer uses several types of files – Swiss pattern files, needle files, burnish files and pivot file/burnishers.

Swiss Pattern File: The Swiss pattern files are similar to files used by machinists except that the edges are parallel and, in most cases, smooth. The smooth sides of the Swiss pattern files avoid damaging areas not to be altered. The cut of the files is much finer than the cut of machinist's files. The cuts range from 00 to 6 – the 6 being the finest of the group.

In this lesson, you should use a 6 inch file with a 1 or 2 cut for roughing out or forming your material and a 6 inch file with a 3 or 4 cut for finishing.

Needle File: These files include square, triangular, flat, knife edge, round, oval, slitting, marking, half round, barrette and crossing. They are commonly about 6 inches long. Some of these files do not have teeth on all their sides. Because of their fine cut, they may be used on small materials, for filing odd-shaped pieces, and in places not easily reached.

Burnish File: The burnish file is similar to the Swiss pattern file except that one side is smooth as well as the two edges. The smooth side is used for burnishing or polishing metals.

Pivot File/Burnisher: This tool has a very fine file on one end and a burnisher on the other. It will be more completely described when you are instructed in using it.

Using a File: Notice that the teeth on any file are pointed away from the tang or handle. Hold the file with the index finger on top of the file and the tang firmly against the heel of the palm. Hold the wrist rigid and the elbow relaxed to serve as a pivot.

Apply light pressure as you push the file forward over the material. Use little or no pressure on the back stroke. This will prevent dulling the teeth and will increase the useful life of the tool. Let the tool do the work.

Clean your files frequently with a fine brass wire file cleaner. This will prevent the teeth from becoming clogged by small shavings or chips that will scratch the material and make more polishing necessary. A fairly good substitute for a brass wire file cleaner is a small flat piece of brass. Draw the edge of the brass across the file parallel with the teeth.

Pin Vise: A pin vise is essentially a small chuck with a short round handle. Some pin vises have chucks on both ends. They are used to hold small round materials while filing or otherwise altering.

Filing Block: A filing block may be made from ¼ inch plywood. Cut a rectangle about 2 ½ inch wide and 6 inches long. Make a ¼ inch hole near one end of the block. Insert a bolt or screw in the hole and fasten the block to the bench so that the block, when swung in working position, extends about 1 ½ inches beyond the front edge of the bench. A right handed person will want the filing block near the right end of the bench.

Cut a V-shaped notch in the middle of the end of the block that protrudes over the edge of the bench. The "V" should not be wider than 3/8 inch at the edge of the block. The length of the "V" should be about 1 inch.

Cut a cross groove about 1/16 inch deep about ½ inch back from the end of the block. The groove will extend completely across the filing block. See Fig 1.

Fig. 1. Filing Block

Materials being filed may be placed on the filing block and held firmly with the pin vise or other tool. This will prevent filing your bench top.

When you have read this far and believe that you have thoroughly in mind what we have told you about files and the pin vise, take the self-check test and convince yourself that you are ready to progress.

Self-Check Test 1

Directions: Choose the letters that indicate the correct answers to the following questions or statements. One or more, or none of the answers may be correct.

1. Swiss pattern files usually have:
   a. Teeth on both sides and both edges.
   b. Teeth on one side and one edge.
   c. Teeth on both sides but at least one edge is smooth.

2. Since the numbers on Swiss pattern files designate the cut, the larger the number, the finer the cut.
   a. True
   b. False

3. Needle files are used for filing:
   a. Small materials.
   b. Odd-shaped pieces.
   c. In difficult places.

4. The file teeth point (a) toward (b) away from the handle.

5. In using a file, you should apply more pressure on the
   a. Forward stroke
   b. Backward stroke

Turn to the key to Test 1 and check your own answers. If you missed any of the answers, read again the text material at the beginning of the lesson.

The Sliding Millimeter Gauge: This gauge uses the metric system. The following table shows the approximate relative values of millimeters and inches. "mm" is an abbreviation for millimeters.

mm	Inches
25.4	1.000
1.0	.040
0.1	.004
0.01	.0004

Fig 2 shows a millimeter gauge. It is calibrated in millimeters. It is used to measure inside and outside diameters and other dimensions. The vernier scale enables you to read the dimensions to the nearest 0.1 mm. If you are careful, you can read it to the nearest 0.05 mm or even more accurately. There are two scales.

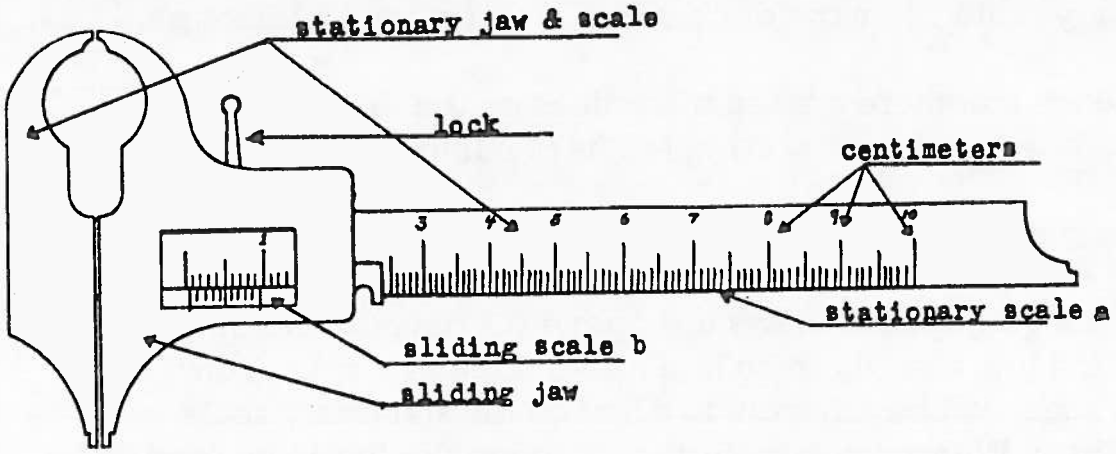


Fig. 2. Sliding Millimeter Gauge

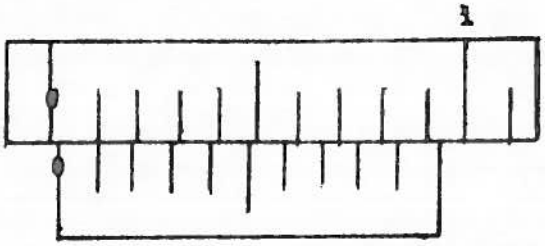
Notice the numbers on the stationary scale. These numbers – 1,2,3, etc. – refer to centimeters. There are ten graduations between each figure. Each graduation represents one millimeter. Ten millimeters equal one centimeter.

Notice the left mark on the sliding scale. We shall call this the zero line on the sliding scale. Slide the scale until the zero line is exactly in line with the number 1 on the stationary scale. The jaws are now exactly one centimeter or ten millimeters apart. We shall refer to this reading as "ten millimeters". Now set the zero line on the sliding scale exactly in line with the number 2. The jaws are now two centimeters or "twenty millimeters" apart. For additional practice, set the sliding scale on 30 mm, 40 mm, and 50 mm. Now set the zero mark on the sliding scale in line with the third graduation on the stationary scale. The jaws will then be 3 mm (slightly less than one-eighth inch) apart.

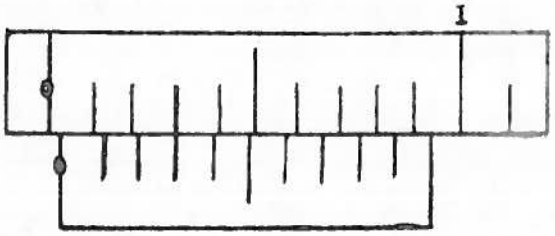
Reading the Vernier: So far we have used only the zero line on the sliding scale. This line is exactly adjacent to a line on the stationary scale when the dimensions are in whole millimeters.

Now notice that there are ten other lines on the Vernier or sliding scale. These are for measuring tenths of millimeters.

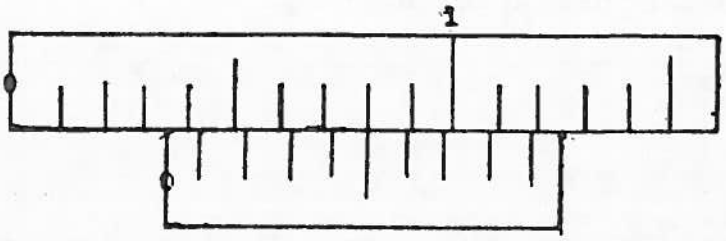
The ten spaces on the sliding scale are together as long as nine spaces on the stationary scale. Therefore, starting from a whole millimeter setting, if the jaws are opened .1 mm, the first line (that is, the first line after the zero line – end of the first space) on the sliding scale will be adjacent to a line on the stationary scale. See a.Fig 3. Widen the jaws further, making the third line (end of third space) adjacent to a line on the stationary scale. This is illustrated in b. Fig 3. The fraction now represented is .3 mm.



a. Fig. 3. Reading of .1 mm.



b. Fig. 3. Reading of .3 mm.



c. Fig. 3. Reading of 3.5 mm.

Similarly, measurements of .3 mm, .4 mm, etc. to .9 mm can be made. Remember that when the zero and tenth lines on the sliding scale are adjacent to lines on the stationary scale, the reading will be in whole millimeters. If, however, any other line on the sliding scale is exactly adjacent to a line on the stationary scale, the reading will end in a fraction. The number of tenths will be the number of the line on the sliding scale that is exactly adjacent to a line on the stationary scale.

Set your gauge to 3 mm. Now, advance the sliding scale until the zero line is half-way between the 3 mm and 4 mm lines on the stationary scale. If it is exactly half-way, the fifth line (or middle long line) on the sliding scale will be adjacent to a line on the stationary scale, See c. Fig 3. The reading is now 3.5 mm.

Self-Check Test 2

Directions: Choose the letters that indicate the correct answers to the following statements or questions. Remember, from none to all of the answers may be correct.

1. One millimeter equals approximately:
   a. 1/8"
   b. .040"
   c. .004"
   d. .0004"

2. Each graduation on the stationary scale of a millimeter gauge represents:
   a. one millimeter
   b. one centimeter
   c. .040"

3. Which line on the sliding scale of the millimeter gauge is adjacent to a line of the stationary scale when the jaws are exactly 3.0 millimeters apart?
   a. zero
   b. middle
   c. last

After you have completed the self-check test, turn to the key and check your answers. If you made a perfect score on your test, proceed to the next section.

The Jeweler's Saw : The jeweler's saw serves the same purpose to the clock repairer as the hack-saw does to the machinist. It looks and is handled more like a carpenter's coping saw, however.

The blades are very small in width and thickness and they come in a variety of cuts. Blades may be purchased in sizes or cuts from #4 (coarse) to #7/0 (very fine). Work in very close places may be done with a jeweler's saw, even where it is impossible to use a needle file.

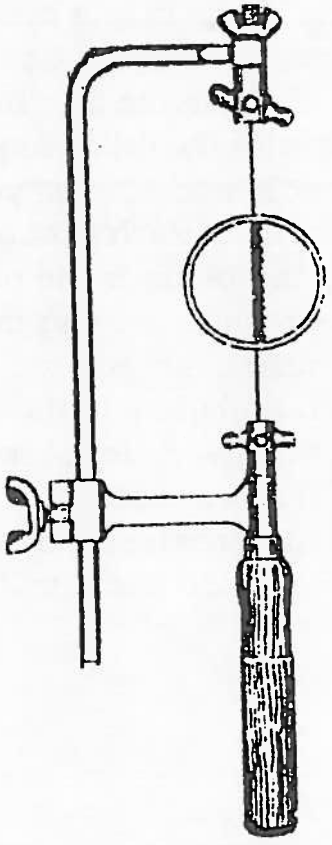


Fig. 4. Jewelers Saw

Care: The blades are small and break easily. To avoid as much breakage as possible, follow a few simple rules. Choose a coarser blade for heavier work and a finer blade for light work. Do not crowd the saw, but allow it to cut with a very light pressure on the cutting (down) stroke. Use little or no pressure on the back (up) stroke. Keep the blade in alignment with the cut and do not allow the blade to become "pinched". Hold the stock to be sawed firmly so that it will not move and bind the blade. Use a little beeswax on the blade for a lubricant. When installing a new blade, adjust the frame for length so that the blade will have at least ¼ inch freedom lengthwise in the brackets. Mount one end of the blade in one bracket with the cutting edge away from the saw frame and the pitch of the teeth toward the handle. See Fig 4. Tighten the first bracket securely when the blade is in alignment with the other bracket (other bracket still loose). Put the handle end against your stomach and the other end against the bench. Push to cause the frame to spring together slightly. Align the blade in the other bracket and tighten the bracket securely while holding the pressure against the handle. This will cause the blade to be taut but not excessively taut. Do not force the blade into the second bracket, but have it located in the first bracket so that it aligns itself into the second bracket. If it is necessary to force the end into the second bracket, when the pressure comes on the blade, there will be undue strain on the blade and it will break quickly when in use.

Use: When the correct blade has been chosen and properly installed in the frame, proceed as follows:

Lay the stock, if flat stock, on the filing block with the scribe lines up and over the "V" slot. Hold the stock down securely with the fingers of one hand. Grip the saw lightly in the fingers of the other hand. Hold the saw vertical and saw with a downward stroke. See Fig 5. Always saw just outside the scribe lines, leaving the scribe lines on the object. This will leave enough metal to dress down to remove the saw marks and to bring the object to size. Always hold the saw loosely in the hand so that on the upward and downward motion the blade can seek its own alignment. In this manner any bind will be quickly noticed and corrected. Apply a light pressure on the downward or cutting stroke. Allow little or no pressure on the upward or back stoke. To apply pressure on the back stroke will "dub" off the teeth and shorten the life of the blade. By applying a light pressure and keeping the blade free, it may be guided around very sharp corners by merely twisting the handle of the saw.

Do not hurry. The time saved in the finish work alone will offset the time gained in forcing the saw, to say nothing of the breakage of blades. When you believe you understand what we have told you about the jeweler's saw, convince yourself by taking Self-Check Test 3.

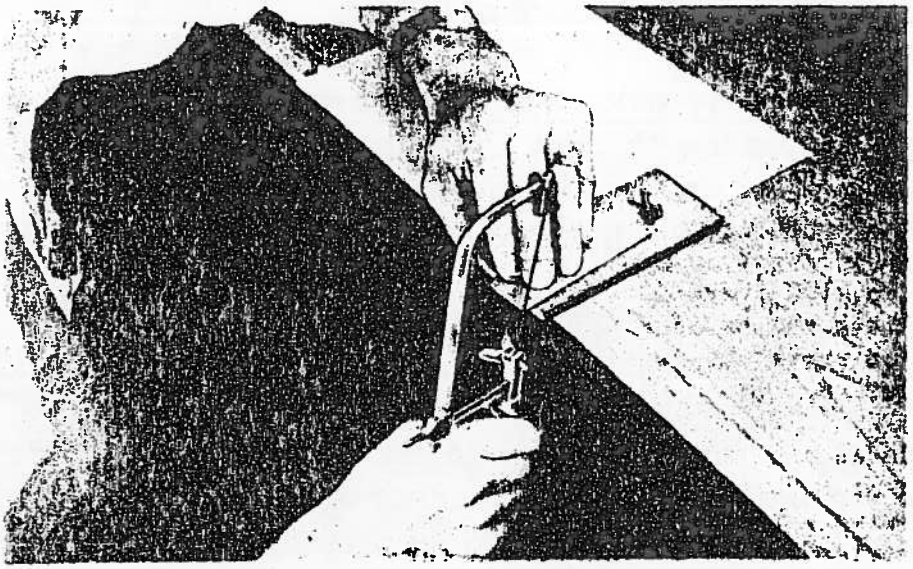


Fig. 5. Using a Jewelers Saw

Self-Check Test 3

Directions: Choose the letters that indicate the right answers to the following statements. From one to all parts of each statement may be correct.

1. Coarse blades are used for heavy coarse work.
   a. True
   b. False

2. The jeweler's saw is used vertically and a light pressure is applied on the:
   a. upward stroke
   b. downward stroke
   c. upward and downward strokes

3. To force the saw will cause it to bind, especially when following an irregular line.
   a. True
   b. False

4. When installing new blades in the saw frame, they must be:
   a. taut in the frame.
   b. loose in the frame.
   c. fairly taut in the frame.
   d. in alignment in the brackets.

5. When sawing out an object, you should saw right down the scribe line to avoid unnecessary filing to finish the part.
   a. True
   b. False

Turn to the key and check your answers. If you missed any of the answers, read again the text material. If you made a perfect score, go ahead.

Problem: To learn to file accurately and cut brass and steel stock to proper length.

Tools and Materials:

Files
Filing block
Pin vise
Jeweler's Saw

Using a Millimeter gauge and saw, cut 2 pieces brass wire 4 mm x 75 mm and 2 pieces steel wire 3.2 mm x 75 mm.

Part A Filing smooth flat ends

Method:

1. Mount a piece of brass wire in the pin vise allowing approximately one inch to be exposed.
2. Hold the pin vise in your left hand so that the stock is vertical in the "V" notch of the filing block. The stock should extend about ¼ inch above the top surface of the filing block.
3. File the end of the stock. Try to make the end surface smooth and "without shadows". If two uneven cuts are made, a small irregularity or "shadow" will be visible. This is the result of not holding the file or stock in the same position during the complete filing process. Try to avoid "shadows".
4. After you have filed the end smooth and no shadows are visible, try to file the end so it will be perpendicular to the length, smooth and no shadows, and so that the stock will stand on end.
5. Reverse the stock and repeat the filing until the brass wire will sand on either end.

6. For additional practice, purposely mutilate the ends of the brass wire and again file the ends, as instructed in 3 and 4 above.
7. Repeat 1 to 5 above, this time using one of the steel wires.

Part B Filing square shanks

Method:

1. Mount your second piece of brass wire in the pin vise allowing approximately ¾ inch to be exposed.
2. Hold the pin vise firmly and level with the filing block with the stock in the groove to prevent it from rolling or sliding.
3. File a flat surface to a length of 10 mm from the end of the stock and to a depth of approximately 1/5 of the diameter of the stock. See a Fig 6. Notice the width of the cut as filing progresses. If the cut is becoming wider at one end, it indicates that you are filing deeper at that end. To correct this, apply slightly more pressure at the other end of the cut. Keep the width of the cut uniform. See b Fig 6. The flat surface should be smooth and free from shadows.

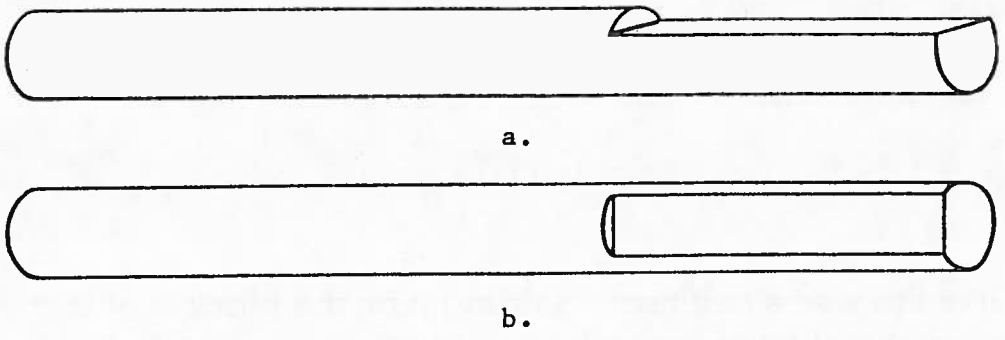


Fig. 6. First Step in Filing Square Shanks
a. Side View b. Vertical View

4. Turn the wire over and lay the flat surface on the filing block – not in the groove. File the opposite (top) side flat to a length of 10 mm from the end and to the same depth as the other side was filed. See Fig 7.

Fig. 7. Second Step in Filing Square Shanks

5. Give the wire a quarter turn. Holding it in the groove and with the previous cuts at right angles to the filing block, make a third cut to a length of 10 mm from the end and the same depth as the other cuts. See Fig 8.

Caution: Now you do not have the curvature of the stock to guide you. You must keep the file and stock horizontal while making this third cut to avoid taper.

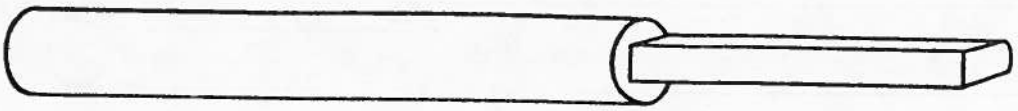


Fig. 8. Third Step in Filing Square Shanks

6. Give the vise a half turn. Holding it on the block (not in the groove) make the final cut. See Fig 9. You will then have a nearly square shank at the end of a round wire. The shank should be 10 mm long. The shoulder should be even on all sides. All flat surfaces should be without shadows. The shank should be without taper and well centered in the stock.

Fig. 9. Completed Square Shank

7. Observe the shank. Notice if it is square, rectangular or diamond shaped.
8. Continue filing until the shank is 2.0 mm square, 10 mm long, centered and without taper, and the flat surfaces are smooth and without shadows.
9. Reverse the stock in the pin vise and repeat 1 to 8 forming a square shank on the other end, having the specifications listed in 8 above. See Fig 10.

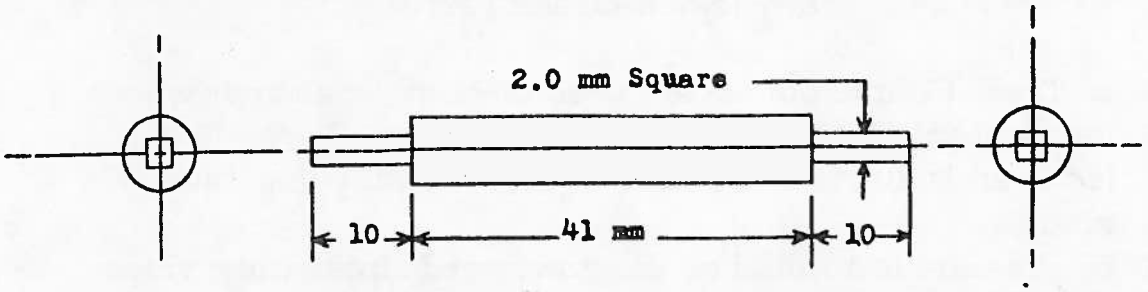


Fig. 10. Completed Project Showing Dimensions

10. Make two more square shanks by repeating 1 to 9, this time using the second piece of steel wire.

Key to Self-Check Test 1

1. c. Teeth on both sides, at least one edge is smooth.
2. a. True, the larger the number, the finer the cut.
3. a,b,c. Needle files are used for filing small materials, odd-shaped pieces and in difficult places.
4. b. The file teeth point away from the handle.
5. a. Pressure should be applied on the forward stroke.

Key to Self-Check Test 2

1. b. .040 inch
2. a or c. one mm or .040 inch
3. a and c. zero and last lines

Key to Self-Check Test 3

1. a. True. Coarse blades are used on heavy materials where the removal of more metal is not important. They will cut faster and will clean themselves more readily than fine blades.
2. b. Pressure is applied on the downward stroke only, since the teeth point toward the handle.
3. a. True. To force the saw will cause it to bind. It will then be difficult to cut irregular lines without breaking blades.
4. c,d. Blades must be taut enough to avoid bending when in use and aligned in the brackets to avoid undue strain.
5. b. False. Saw just outside the scribe line to leave metal enough to size and finish the object with files, emery sticks, etc.

Mail to the School the following materials:

1. Brass wire with ends filed smooth and without shadows, and perpendicular to the sides.
2. Steel wire with ends filed smooth and without shadows, and perpendicular to the sides.
3. Brass wire with square shanks 2.0 mm square x 10 mm long on each end, shanks centered and without taper, and flat surface smooth and without shadows.
4. Steel wire with square shanks 2.0 mm square x 10 mm long on each end, shanks centered and without taper, and flat surface smooth and without shadows.
5. A brief summary of any difficulties you experienced in learning to file accurately. The summary should tell how you overcame the difficulties. Use Page 20 of this lesson for your summary.

Clock & Watch Repair

Student's Report – Lesson 1

Student's Name _____

Address _____

City _____ State _____ Zip _____

Difficulties:	Solutions:
1.	1.
2.	2.
3.	3.

Is there any phase of the work covered in Lesson 1 that you do not thoroughly understand? _____ If so, what?_____

_____

_____

Instructor's Score Sheet
Lesson 1

	Possible Score	Student's Score
1. Brass Wire		
a. Smooth ends without shadow	10	_____
b. Will it stand on either end?	10	_____
2. Steel Wire		
a. Smooth ends without shadows	10	_____
b. Will it stand on either end?	10	_____
3. Brass Wire with Shanks		
a. Conformity to shank size 2mmx10mm	4	_____
b. Square	4	_____
c. Centered in stock	4	_____
d. Absence of taper	4	_____
e. Smooth and without shadows	4	_____
4. Steel Wire with Shanks		
a. Conformity of shank size 2mmx10mm	4	_____
b. Square	4	_____
c. Centered	4	_____
d. Absence of taper	4	_____
e. Smooth and without shadows	4	_____
5. Written Report	20	_____
Student's Total Score		_____

Instructor's Initials _____ Date _____

Instructor's Comments

LESSON 2

ROUND, TAPER AND SQUARE FILING

In Lesson 1 you learned to file flat surfaces accurately. You are now concerned with learning to file round shanks, cylinders, and straight tapers.

Job 1

Problem: To make two bezel openers.
To make one burnisher.
To make two double end bench keys.

Tools and Materials:

Files	Emery sticks
Pin Vise	4 pieces crucible steel wire, 3.2mm x 75mm
Millimeter gauge	4 pieces crucible steel wire, 3.2mm x 65mm

Method:

A. Make a Jewel Burnisher

1. Insert one piece of crucible steel in your pin vise, leaving about 15 mm exposed.

2. Lay the exposed piece of stock in the groove of your filing block.

3. Grasp the end of the pin vise lightly, with the thumb, forefinger, and middle finger. See Fig. 1.

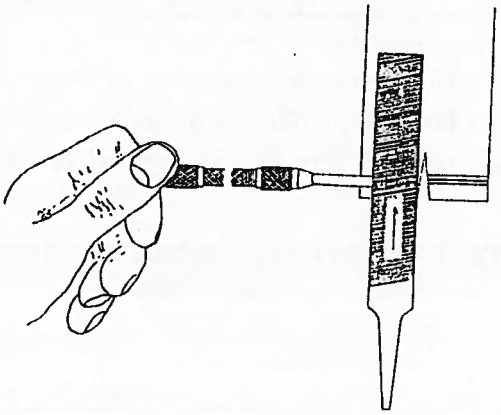


Fig. 1. Roll-Filing

4. Rotate the pin vise backward and forward, causing the pin vise and stock to make at least one complete revolution on each forward movement.

5. When you have practiced rotating the pin vise and can be sure that it makes a complete revolution each time the direction of motion is reversed, you are ready to begin filing.

6. Using your 6-inch Swiss pattern file, apply light pressure on the file with a forward movement of the right hand, while the left hand is rotating the top of the stock toward the file. Remember, the stock must be kept in the groove during this process to keep it from sliding across the filing block. Now, while the right hand is being drawn back, with little or no pressure on the file, rotate the stock from the file, that is, forward. This is called "roll-filing." Practice "roll-filing," keeping light pressure on the file and using a light grip at the end of the pin vise with the tips of the thumb and two fingers.

   If you find flat areas forming on the stock or if the stock is becoming egg-shaped, you are not rotating it a complete revolution with each movement.

   Accomplish a rhythm in which the right hand moves forward as the stock is rotated backward and vice versa. See Fig. 1.

7. Make a cylindrical shank 10mm long and slightly more than 1.5mm in diameter at one end of the stock as shown in Fig. 2.

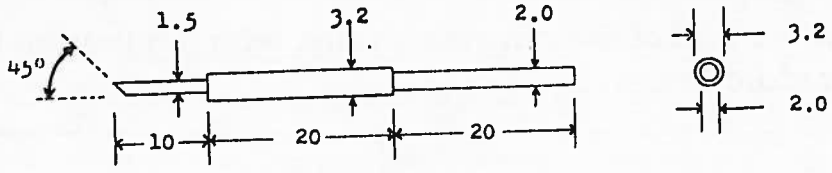


Fig. 2. Jewel Burnisher (dimensions in millimeters)

8. Measure 20mm from the shoulder and make a small file mark. This will mark the shoulder for the other end of the tool.

9. Measure 20mm from the mark made in paragraph 8, above, and

make another mark. This should be 50mm from the end of the shank and will be the over-all length.

10. Insert the stock in the pin vise-shank first- leaving both marks and 5 mm additional exposed.

11. Using the corner of your file, roll-file a deep V-shaped groove at the last file mark you made.

12. When the groove is deep enough, the end may be broken off without danger of bending the stock you need for your tool. Break the end off at the "V".

13. File the end of the stock flat and perpendicular to the stock.

14. Roll-file a shank 20 mm long (to the file mark) and slightly more than 2 mm in diameter.

    Emery Sticks: Emery sticks are flat pieces of wood covered with emery paper. They are available in a variety of grits. The coarser grits are used to remove file marks or deep scratches. Fine grits are used for removing shallow scratches.

15. Using a coarse emery stick, about number 1 or 2 grit, remove the file marks from the shank, using the same method as in roll-filing, except that the emery stick replaces the file. Caution: Be careful you do not reduce the diameter of the shank below 2 mm.

16. Using a fine emery stick, number 3/0 or 4/0, remove the shallow scratches left by the coarse emery stick. The shank should now measure exactly 2 mm in diameter and should look semi polished.

17. Using the emery sticks as above, finish the first shank. Its diameter should be exactly 1.5 mm.

18. File the end of the short shank to an angle of approximately 45°. Finish the end with emery sticks. The end should be flat and smooth. The edges should not be rounded. To avoid rounding the edges, be careful to hold the emery sticks parallel with the surface.

19. Your pin vise has probably left scratches on the body of the tool.

B. Make a Short Taper Bezel Opener

1. Chuck the second piece of crucible steel in the pin vise, leaving about 15 mm exposed.

2. Roll-file a straight taper from the end extending about 10 mm from the end. This is done similar to roll-filing a cylindrical shank, except that the end of the pin vise is lowered to cause the correct taper angle. Caution: You should cut a straight taper-not a rounded taper. See Fig. 3.

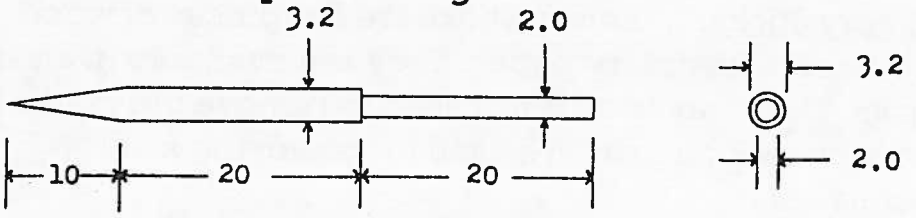


Fig. 3. Short Taper Bezel Opener (dimensions in millimeters)

Check the taper occasionally with a straight edge to see that it is not rounded. A rounded taper is caused by either changing the angle of the stock or by neglecting to keep the file parallel with the filing block on all strokes.

3. When you have a straight taper, 10 mm long, and to a point, finish the filed area with emery sticks.

4. Remove the stock from the pin vise and make one file mark 30 mm from the point and a second mark 50 mm from the point.

5. Insert the pointed end in the pin vise, allowing 5 mm beyond the first file mark to be exposed.

6. Cut a deep groove at the second mark and break off and finish off the end.

7. Roll-file and emery a shank from the first mark to the end. The diameter should be 2 mm when finished.

8. Finish the entire tool with emery sticks.

C. Make a Long taper Bezel opener

1. Repeat steps 1 to 8 as above, making a bezel opener of the dimensions shown in Fig. 4 below.

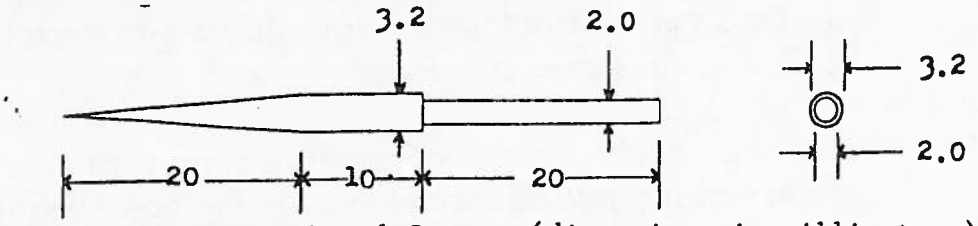


Fig. 4. Long Taper Bezel Opener (dimensions in millimeters)

D. Make a Set of Bench Keys

1. Insert one piece of 3.2 mm x 65 mm crucible steel stock in your pin vise leaving approximately 10 or 12 mm exposed.

2. Roll-file the end to a diameter of 1.9 mm and for a length of 6mm.

3. Using your 6" file, make a square shank. This shank is to be 1.4 mm square when fished with your 3 or 4 cut file. You should, therefore, stop using the 1 or 2 cut file when the shank is slightly larger than 1.4 mm square and centered in the stock.

4. Using your fine file, finish the square shank. It should then be exactly 1.4 mm square, 6 mm long, centered, without taper, and the flat surfaces should be smooth and without shadows. Do not use emery sticks for finishing the shank because of their tendency to round the corners. See a, Fig. 5.

It is absolutely essential that the shank be exactly 1.4 mm square and that the other shanks that you will make will be of the exact dimensions specified.

5. Reverse the stock in the pin vise, and roll-file the end to a diameter of 1.7 mm for a length of 6 mm and following steps 3 and 4 above, make a shank on the end 1.2 mm square. See b, Fig. 5.

6. Make a file mark 25 mm from each shoulder. File a deep groove at each file mark and break off the excess material.

7. Roll-file a very slight taper, beginning 3 mm from the shoulders, as shown in c, Fig. 5.

8. Using your second piece of crucible steel repeat steps 1 to 7 above, making two square shanks to the specifications below.

9. Roll-file one end of the second piece of stock to 1.5 in diameter and 6 mm in length and make the 1.1 mm square shank, as shown in d, Fig. 5.

10. Reverse the stock in your pin vise, roll-file the end to 1.4 mm in diameter and 6 mm in length. Form this end into the shank 1.0 mm square, as shown in e, Fig. 5.

11. Use the 9.3 mm aluminum stock. File the ends flat. The final length should be 50 mm for each of these two identical pieces.

12. Drill a 3 mm hole, 25 mm deep into each end of the two aluminum pieces using care to center every hole, as shown in c, Fig. 5. With a small brass hammer, tap the tapered end of each "plug" into the aluminum hole until it is firmly seated. Pair the larger squares, 1.4 mm and 1.2 mm, into the same handle. Pair the remaining two smaller plugs into the other aluminum handle as before.

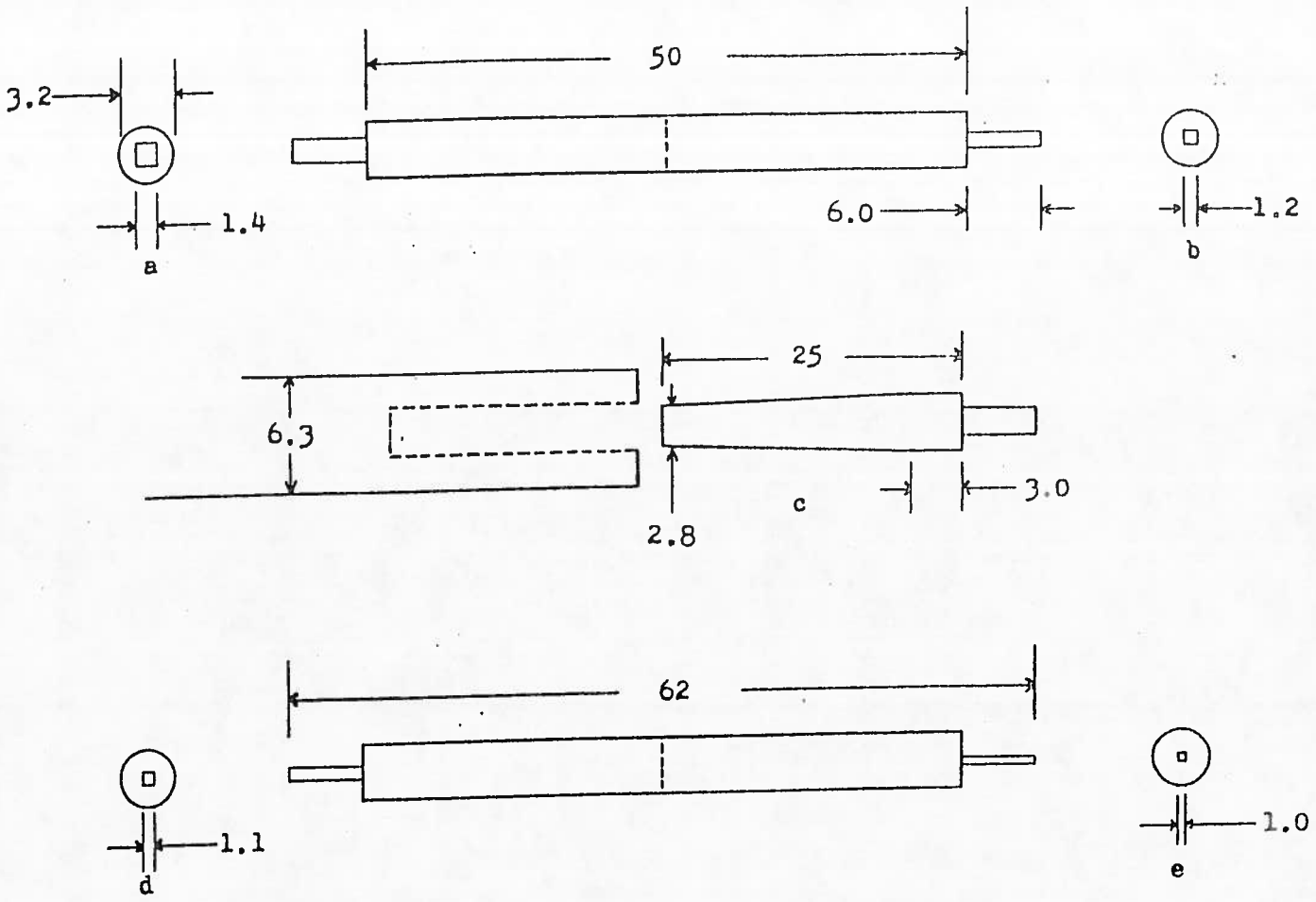


Fig. 5. Bench Keys (dimensions in millimeters)

Mail to the School the following materials:

1. The four tools you have just completed: burnisher, long taper bezel opener, bench key with 1.4 mm shank and bench key with 1.2 mm shank
2. A brief summary of any difficulties you experienced in round, taper and square filing. The summary should tell how you overcame your difficulties. Use Page 8 of this lesson for your summary.

Clock & Watch Repair
Student's Report – Lesson 2

Student's Name _____

Address _____

City _____ State _____ Zip Code _____

Difficulties:	Solutions:
1.	1.
2.	2.
3.	3.

Is there any phase of the work covered in Lesson 2 that you do not thoroughly understand?_____ If so, what? _____

_____

_____

Instructor's Score Sheet
Lesson 2

	Possible Score	Student's Score
1. Burnisher		
a. Roundness and concentricity of shanks	5	_____
b. Dimensions	5	_____
c. Finish	4	_____
2. Long Taper Bezel Opener		
a. Roundness and concentricity of shank	5	_____
b. Roundness and concentricity of taper	5	_____
c. Straightness of taper	4	_____
d. Dimensions	4	_____
e. Finish	4	_____
3. Bench Key 1.4 mm		
a. Dimensions of shank	7	_____
b. Shape of shank	5	_____
c. Centering of shank	5	_____
d. Taper of handle end	5	_____
4. Bench Key 1.2 mm		
a. Dimensions of shank	7	_____
b. Shape of shank	5	_____
c. Centering of shank	5	_____
d. Taper of handle end	5	_____
5. Written Report	20	_____

Student's Total Score _____

Instructor's Initials

Date_____

Instructor's Comments

LESSON 3

FURTHER APPLICATION OF ROUND AND TAPER FILING AND THE HEAT TREATMENT OF STEEL AND ALLOY METALS

In Lesson 3, Part 1, you will file and finish straight tapers as you make a set of six punches. In Part 2 you will learn to heat treat metals.

PART 1 Making Punches

Job

Problem: To make a set of six punches. Make all punches approximately 70 mm in length:

Tools and Materials:

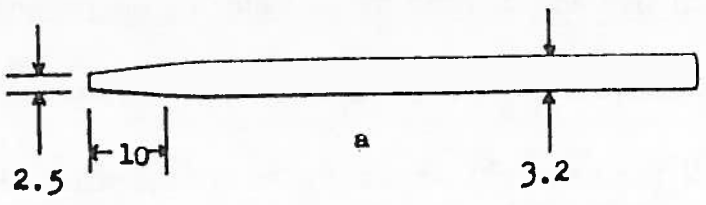
Files	Emery Sticks
Pin Vise	2 pieces crucible steel 3.2 mm x 75 mm
MM gauge	2 pieces crucible steel 4.7 mm x 75 mm

Method:

A. Hole-Closing Punch

This punch will be used for reducing the size of pivot holes that have become worn.

1. Using 3.2 mm stock, roll-file and finish with emery sticks a straight taper at one end. Reduce the diameter at the end of the stock to 2.5 mm. The taper should extend 10 mm from the end, as shown in a, Fig. 1.



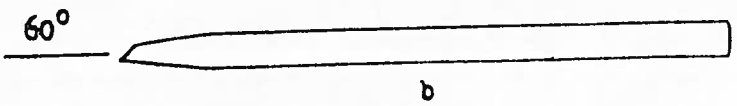


Fig. 1. Angle-Face Hole-Closing Punch

2. File the end at a slant to an angle of 60 degrees with the center line of the stock. See b, Fig. 1.

B. Three-Cornered Punch

This punch also will be used for hole closing operations.

1. Insert a piece of 4.7 mm crucible steel into your pinvise.

2. Roll-file a straight taper at the end of the stock. Reduce the diameter at the end to 2.5 mm. The taper should extend 11 mm from the end as shown in a, Fig. 2.

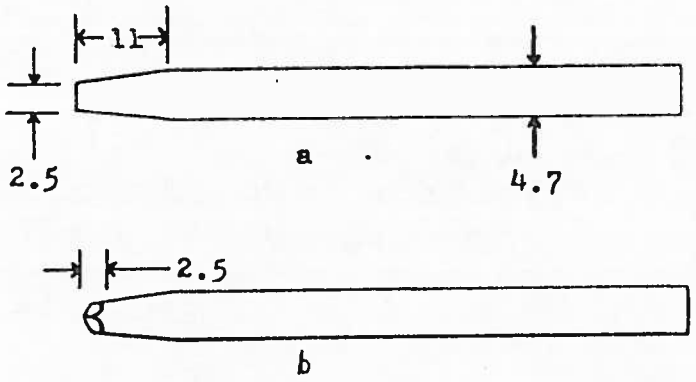


Fig. 2. Three-Cornered Punch

3. File three flat surfaces on the 2.5 mm end to extend back on the taper 2.5 mm. Make the surfaces equal, coming to a sharp point and well centered at the end. This is important. See b, Fig. 2.

C. Round-Nose Punch

This punch also will be used for hole closing operations.

1. Insert a piece of 4.7 mm crucible steel into your pinvise.

2. Roll-file a straight taper at the end of the stock. Reduce the diameter at the end to 2.5 mm. The taper should extend 10 mm from the end.

3. File the end to a ball point and finish with a coarse, then fine emery stick, making a smooth ball point at the end of the punch. See Fig. 3.

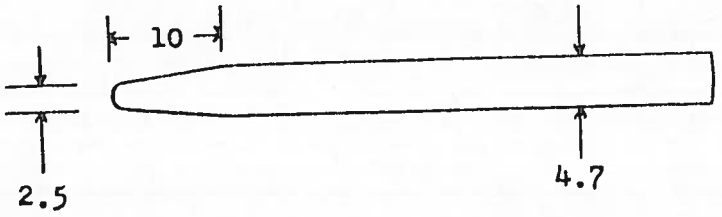


Fig. 3. Round-Nose Punch

D. Scribe

This scribe will be used for marking on metal.

1. Insert a piece of 3.2 mm stock into your pinvise, allowing 25 mm to be exposed.

2. Roll-file a straight taper extending 20 mm from the end. The end should be pointed, the point being sharp and centered in the stock. See Fig. 4.

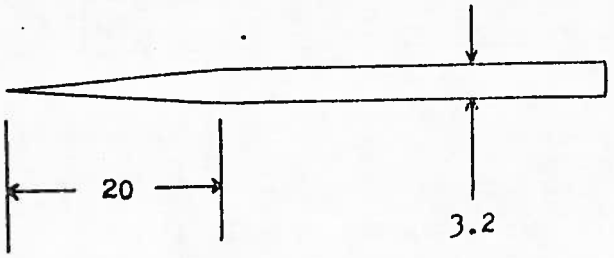


Fig. 4. Scribe

3. Finish with coarse and fine emery sticks.

E. Center Punch

The center punch will be used for striking centers.

1. Roll-file a taper on one end of a piece of 4.7 mm crucible steel. Reduce the diameter at the end to 1.5 mm. The taper should extend 10 mm from the end. See a, Fig. 5.

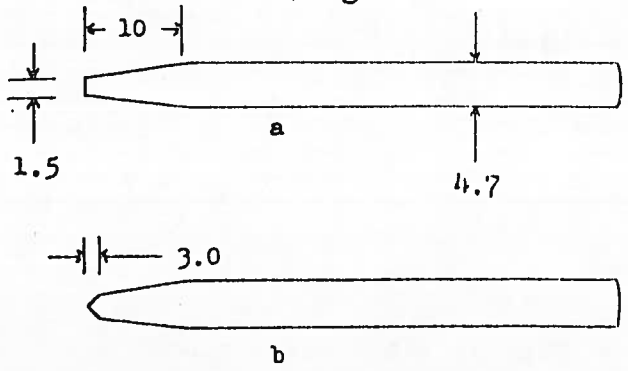


Fig. 5. Center Punch

2. Roll-file an additional taper at a steeper angle. This taper will begin 3 mm from the end and will reduce the end to a sharp point. See b, Fig. 5.

F. Flat-Nose General Purpose Punch

1. Roll-file a straight taper at one end of a piece of 4.7 mm crucible steel. Make the diameter at the end 1.5 mm. The taper should extend 10 mm from the end. See Fig. 6.

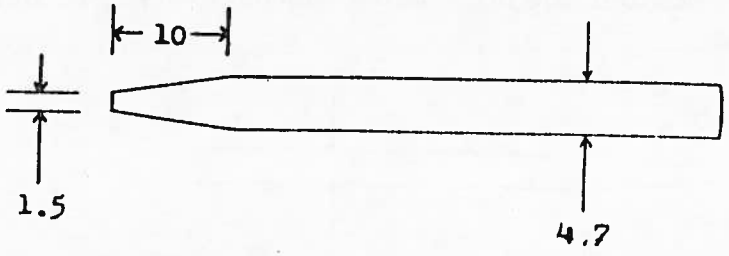


Fig. 6. Flat-Nose General Purpose Punch

G. Finishing the Punches

1. Taking each punch in succession, insert the point in your pinvise and finish off the opposite end, removing all burrs and giving the ends a finished look.

2. Check to see that all the tools have been finished with coarse and fine emery sticks.

PART II Heat Treatment of Steel and Alloy Metals

Know your Steel: Most steel tools and steel parts are made from "soft" crucible steel. This steel stock must be soft to be worked readily. It is then hardened to meet the requirements of the specific job for which it is intended. Much time is required to make certain parts. It is very discouraging to make a part and then find that it was made from iron that will not respond to heat treatment.

Kinds of Steel: There are numerous kinds of steel. They require different methods of heat treatment. Cold rolled steel, iron, and very low carbon steel require case or surface hardening. They will not respond to the method explained in this packet which is suitable for fairly high carbon steel, referred to as crucible steel.

Tests for Steel: Hold the stock against an emery wheel. If the sparks are a bright color and burst like a sparkler as they leave the wheel, it is likely to be steel. If the sparks are dull red, it is probably iron. Steel is usually bright in color as if it has been polished. Iron is dull gray. If you cannot decide whether the stock is iron or steel, try hardening a small piece before making it into a tool. The steps for hardening will be explained later.

Hardening and Tempering: There are two distinct steps or phases in the heat treatment operation. They are "hardening" and "tempering." Do not confuse these terms.

1. Hardening: Hardening means to harden. When a piece of crucible steel is hardened, it is glass hard. It is very brittle and has little or no spring. Steel in this state is very good where there is wear but very little stress. This steel is worthless for certain delicate parts where strain or stress is applied. It breaks very easily.

2. Tempering: Tempering is the reducing of the glass hardness to meet the requirements of the specific part or tool. The more the hardness is drawn or tempered, the more flexible the steel becomes. As the metal is tempered its wearing qualities decrease and its elasticity increases. Therefore, it is necessary to know for what the part is to be used and to govern the tempering accordingly.

How to Harden Crucible Steel: Have tools or parts finished and polished as highly as possible before heat treatment, as the cutting and polishing will be much more difficult after the hardening process. The final polishing will be done after the part has been hardened and tempered.

Grasp the part or tool with small fire tongs, wire, or heating pan, depending on the size of the part. Warm very slightly (just pass through flame) and dip in boric acid powder. Jar or dust off all the loose powder leaving a light gray film. Go back into the flame. Be careful not to burn odd shaped pieces. Heat the heavy areas and allow the heat to carry to the lighter areas. Heat evenly to a light cherry red and quickly plunge into cold water. Long pieces should be submerged lengthwise to prevent as much warpage as possible.

Test for Glass Hardness: Test the hardened piece with a file. If the file still cuts the stock as before, clean up and go through the hardening process again. But if the file fails to cut and merely slips over the surface, the part is glass hard. Be careful during this stage as the piece will break very easily. Polish all discoloration from the part. This is important as any discoloration will mix with the tempering colors and will not be a true temper color.

How to Temper Hardened Crucible Steel: Metal that is glass hard is suitable where wear only is desired but it is very brittle and there is no spring in it. It would not do for screw-drivers, tweezers, springs, or anything where a toughness was desired. Reducing the hardness and increasing the tenacity is done by again heating the metal. A low heat reduces it a little and a little higher temperature reduces it a little more and so on until it is reduced back to where it was originally. The different stages or temperatures are shown by the colors of the metal at the different temperatures. The lowest temperature brings in a pale straw color and as the temperature goes higher the color darkens, from a light straw to a medium straw, dark straw, brown, purple, deep blue, and finally to a pale blue or gray which is too soft for a tool or part. Cool in water if necessary to stop the heat from going higher; otherwise just remove from the heat and allow the temperature to fall. Each tool or part is a problem in itself as to what color is proper. For instance, tweezers and screw-drivers are drawn to a brown. Deep blue is used for most springs and staffs.

Heat Control: There are several methods of heat control. The use of flame to temper small parts is severe and usually one portion of the part is drawn too far while another portion is too brittle. The use of the sand pan allows the temperature to rise evenly and slowly. To properly control the heat, use a heavy pie pan or other shallow pan and a small burner such as a Bunson. Mount the pan over the burner and fill with white sea sand to a depth of 1/4 to 1/2 inch, depending on the size of the parts to be tempered. The sand gives a nice background so the colors may be seen and also controls the temperature. An electric or kitchen stove may be used for source of heat.

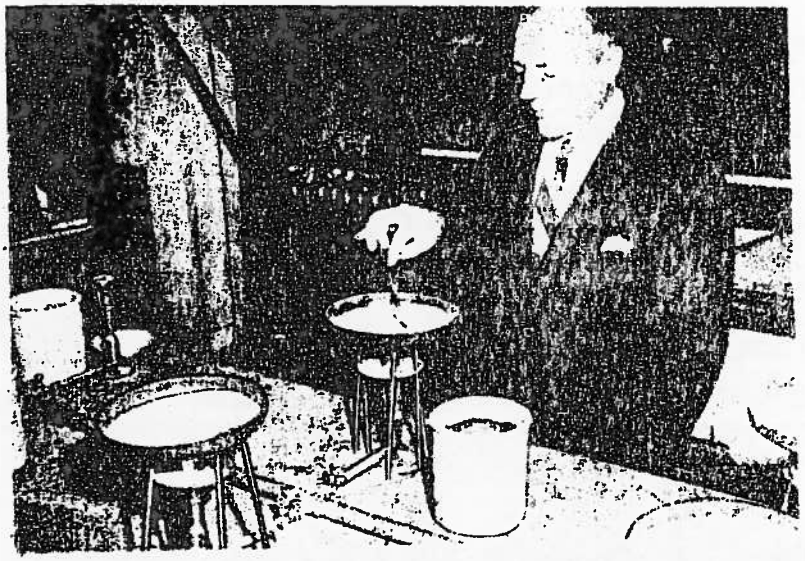


Fig. 7. Tempering with a Sand Pan

After the part has been hardened and all discoloration removed, place the part on the hot sand. On odd shaped pieces allow the very small areas to extend up off the sand and allow the heavier areas to contact the sand. In this manner the light areas will not be drawn ahead of the heavier areas. A little shift of the part will be necessary at times to bring the color up uniformly. Watch the part carefully and when the desired color has been reached, lift the part from the sand quickly.

Parts may be tempered with a small flame, but care must be exercised to avoid drawing small areas too fast as compared to the heavier areas. Play the heavy areas high in the flame and keep shifting until the color is uniform. When the part has the desired color, quickly remove it from the heat.

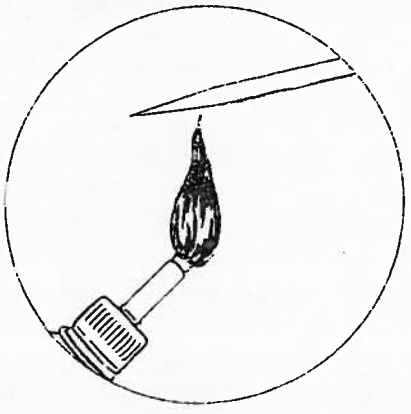


Fig. 8 Tempering with a Flame

Removing Color: If the color of the tempered part is to be removed, dip the part in blue remover and quickly clean and rinse with alcohol. The color may be left on tools to demote the hardness of the tool. The color retards rust to a certain extent.

Annealing Steel: Hardened steel which is too hard to cut or form may be softened by heating to a dull red and cooling very slowly. If it is to be reduced only to a certain point so hardening and tempering will not be necessary after forming or cutting, draw to the desired color and cool to prevent it from getting softer.

Annealing Brass, Bold, Silver, etc: Alloy metals are handled quite the reverse from steel. To soften a piece of brass, gold, etc., heat to a cherry red and quickly plunge in cold water.

Hardening Brass, Gold, Silver, etc: Most alloys may be hardened by pounding, rolling or drawing through a draw plate.

When you believe you understand what we have told you about heat treatment of metals, convince yourself by taking the self-check test.

Self-Check Test 3

Directions: Choose the letters that indicate the right answers to the following statements. From one to all parts of each statement may be correct.

1. Iron and steel may be hardened by heating to a light cherry red and quickly quenching.

    a. True
    b. False

2. Glass hardened steel is suitable

    a. where spring is desired.
    b. where there is no wear.
    c. where there is wear and a minimum of strain.

3. The first color in a tempering operation is the

   a. hardest.
   b. softest.

4. Pale blue or gray color is suitable for

   a. staffs.
   b. springs.
   c. where there is a maximum of wear.
   d. none of these.

5. The final polish on steel parts should be done.

   a. before heat treatment.
   b. after heat treatment.
   c. after the part has been hardened only.

Turn to the key. If you have missed any of the answers, read again the text material at the beginning of Part II. If you made a perfect score begin the problem in Part II.

Job

Problem: To heat treat steel tools and wires.

Tools and Materials:

Files
Alcohol lamp and methol alcohol
Boric acid powder
Fire tongs or tweezers
Emery Sticks
2 pieces crucible steel wire 1.8 mm x 50 mm
2 pieces crucible steel wire 1.0 mm x 50 mm
Jar of cold water

Method:

A. Hardening Crucible Steel Wires (1.8 mm):

1. Holding one of the 1.8 mm pieces of stock near one end with the fire tweezers pass the other end through the flame of the alcohol lamp.

2. When the stock is quite warm but not hot, stick the heated end into the boric acid powder to a depth of one inch or more.

3. Tap lightly to remove excess powder.

4. Return the stock to the flame. Heat it until it becomes light cherry red. Keep moving the stock about slightly while in the flame to help distribute the heat evenly.

5. When about one inch of the end of the stock has become uniform in color, quickly plunge it in cold water. This should make it glass hard.

6. Try the file on the hardened area for glass hardness.

7. If the file cuts the steel, the hardening process has failed. It will be necessary in this case to remove the fire coating or discoloration with a fine emery stick and repeat steps 1 to 6.

8. When the file does not cut but "whistles" across the stock, the operation is successful and the stock is glass hard.

9. Test for glass hardness by breaking a small piece from the end of the stock with a pair of pliers.

10. Harden the second piece of 1.8 stock to glass hardness. Do not break this one.

B. Tempering:

1. Remove with emery stick all the fire coating from the stock hardened in 10 above. It is absolutely necessary that all the discoloration be removed and that the metal is bright and shiny.

2. Holding the hardened stock well above the flame, heat slowly until a light straw color is observed. Remove from flame quickly. It will be necessary in this process to keep turning the piece back and forth. Also avoid the application of heat at the extreme end. This causes temperature at the end to rise too fast. The end would then be softer than the remaining portion. Steel tempered to light straw is suitable for cutting tools. It is still extremely hard but not quite so brittle as a glass hard piece. Figure 8, shows the proper way to heat a scribe when tempering it.

3. Heat the stock some more, until it darkens to a medium straw color. Remove the stock from the flame. Steel of this temper is suitable for more delicate cutting tools than steel tempered to a light straw.

4. Back to the flame again. This time remove the stock when it has reached a dark straw color. This hardness is suitable for certain punches. It is still hard but has lost a portion of its brittleness.

5. Now heat the stock until it becomes a brown. This color indicates a hardness suitable for screw-drivers, tweezers, taps and dies and tools of this nature.

6. Heat the stock again. You will next observe a purple color and blue will follow immediately. Remove from the heat as soon as the steel is dark blue. This blue is the first blue you will recognize after the purple fades. Dark blue still is extremely flexible and is used for springs and staffs.

7. Test the treated portion for flexibility. Try to bend it. If it does not spring back to near its original shape it is too soft. This indicates that you did not remove it from the flame immediately when it reached dark blue color.

8. Heat the stock again, this time until it becomes light blue or gray. It is now back where you started. It is worthless until it has been brought to glass hardness again and tempered to the desired hardness.

9. Glass harden the stock again. Polish off all discoloration. Temper to a dark blue.

C. Hardening and Tempering of Small Stock (1.0 mm):

1. Harden both ends of both small pieces of stock.

2. Temper one end of the first piece to a light straw and the other end to a medium straw.

3. Temper one end of the second piece to a dark straw and the other end to a brown.

D. Heat Treating Tools You Have Made:

Source of heat (a or b)
a. Propane torch such as Burnzomatic
b. Burner on gas kitchen stove

1. Bring the burnisher, bezel openers, bench keys and all the punches to a glass hardness. The glass hardness should extend to a distance of at least 1/2 inch from the end and one inch would be better.

2. Temper them to the colors indicated in the table below:

Tool	Color	Tool	Color
Burnisher	medium straw	3-cornered punch	dark straw
Bezel opener (short)	medium straw	round-nose punch	medium straw
Bezel opener (long)	dark straw	scribe	medium straw
Bench keys	purple	center punch	medium straw
Hole closing punch	brown	flat-nose punch	medium straw

Key to Self-Check Test 3

1. b. False. Iron and low carbon steel must be case hardened.
2. c. Where there is wear and a minimum of strain.
3. a. Hardest.
4. d. None of these.
5. b. After heat treatment.

Mail to the School the following materials:

1. Four pieces of crucible steel tempered in accordance with job instructions. Do not remove the tempering color so that it can be checked for accuracy.
2. Tools heat treated as listed: Burnisher, Bezel Opener (short), Bezel Opener (long), Bench Keys, Hole Closing Punch, 3-Cornered Punch, Round-Nose Punch, Scribe, Center Punch, Flat-Nose Punch. Do not remove the tempering color so that it can be checked for accuracy.
3. Brief summary of any difficulties you experienced in the making of the six punches and in heat treating the tools and crucible steel stock. The summary should tell how you overcame your difficulties. Use Page 14 of this Lesson for your summary.

Clock & Watch Repair
Student's Report -- Lesson 3

Student's Name _____

Address _____

City _____ State _____ Zip_____

PART I

Difficulties:	Solutions:
1.	1.
2.	2.
3.	3.

PART II

Difficulties:	Solutions:
1.	1.
2.	2.
3.	3.

Is there any phase of this work covered in Lesson 3 that you do not thoroughly understand? ____ If so, what? _____

INSTRUCTOR'S SCORE SHEET
LESSON 3

	Possible Score	Student's Score
1. Four steel wires		
a. Glass Hardness	10	_____
b. Temper Colors (1.8mm stock should be blue)	5	_____
(1.0mm stock, 2 pieces, 4 ends colors are light, medium and dark straw and brown)	15	_____
2. Temper colors on tools		
a. Burnisher: medium straw	5	_____
b. Bezel Opener (short): medium straw	5	_____
c. Bezel Opener (long): dark straw	5	_____
d. Bench Keys: purple	5	_____
e. Angle-face Punch: brown	10	_____
f. Shape of Punch	5	_____
g. Three-Cornered Punch: dark straw	10	_____
h. Shape of Punch	5	_____
3. Written Report	20	_____
	Student's Score	_____

Instructor's Initials _____ Date _____

Instructor's Comments

EFFECT OF TEMPERING TEMPERATURE UPON THE PHYSICAL PROPERTIES OF HARDENED DRILL ROD (1.00% CARBON)

TEMP. 0° F APPROX.	COLOR	HARDNESS	PHYSICAL PROPERTIES	TOUGHNESS	APPLICATION
300°	Light Straw	DECREASES ↓	Stress Relieved, Very hard, Brittle	INCREASES ↓	Cutting Tools, Gravers
340°	Straw		Hard, Strong		Cutting Tools requiring greater strengths:— (Undercutting tools, Boring Tools, Taps, Drills.) Watch parts requiring hardness and strength (Winding Pinion, Clutch, Click, Clutch Lever.)
375°	Brown		Best combination of Hardness and toughness		Parts and Tools requiring Hardness, Strength and Resistance to shock. (Winding Stem, Ratchet and Crown Wheels, Setting Lever, Chronograph Pillar Wheel Jumper.)
450°	Purple		Brittle		No Practical Use.
600°	Dark Blue		Flexible		Light Springs (Clutch, Click, Yoke or Setting Bridge.) Tools requiring strength and flexibility (Colleting Arbors, Screw Driver Blades.)
650°	Light Blue		Increased Flexibility Machinable		Heavier Springs and springs of lighter tension (Chronograph Hammer Spring, Minute recording jumper.) Steel and parts that are to be machined after hardening and tempering (Steel for balance staffs, stems when slot will be cut after hardening.

HOW TO HARDEN AND TEMPER STEEL

The process of hardening and tempering steel is very important for you to understand. If a true understanding of this is not attained, you will make many mistakes that you will find very puzzling throughout your training.

When you harden steel, you are making it very brittle and fragile. This state is not desirable for any practical purpose. This is the reason we temper, or soften, the steel.

First of all we make sure that the piece of steel to be hardened is perfectly polished and free of all dirt and oil. If it is not clean, the terrific heat will burn the dirt or oil right into the steel making it extremely difficult to polish out.

Heat the steel slightly over the flame, then roll it around in the boric acid until you have a thin film of acid on the steel. The boric acid will help prevent a fire coat or discoloration of the steel and make it easier to polish.

Take your steel and heat it slowly over the flame until it is a dull cherry red, making sure that the color is even and no hot spots, which you will have if there are light red places on the steel.. After heating the steel, do not hesitate and look at the steel; it will cool a little bit. Quench the red steel in cool water, driving it straight into the water, do not put the piece into the water at an angle, this will tend to warp it.

Check the steel to make sure that it is hard by filing it. If the file marks, it is still soft and must be hardened again. If it is hard, the file will not mark it and will make a ringing sound as it passes across the steel. If the file marks the steel, you will have to re-harden it.

After making sure that the steel is hard, polish it to a mirror finish, being careful not to touch it with anything oily or with your fingers. Wipe the steel off with a rag saturated with alcohol before proceeding.

Before continuing, remember one thing: the word temper comes from the word temperature. Tempering, whether done over a flame, in an oven, or in sand, must be done correctly to be effective. It must be remembered that any polished piece of steel, hardened or not, that is heated will turn the temper colors. The temper colors are simply a temperature gauge telling you how hot the steel has been. Slightly heating the steel will cause it to turn to a light straw color. This indicates that the steel has been heated to approximately 300 degrees. This temperature is desirable if you are trying to make a tool that will cut other steel, such as a graver. Light straw shows that the stress has been removed from the steel.

If the steel is left in the heat a little more (approximately 340 degrees) it will turn straw color. This is a little softer than the light straw and a little stronger. The steel will be less apt to break or shatter on you. This is useful if you are trying to make cutting tools that require more strength such as drills, bores, or taps.

Leaving the steel in longer, 375 degrees, it will turn brown. This is just a little tougher and some watch parts can be made out of this (ratchet wheels, crown wheels, and setting levers, etc.)

At 450 degrees the steel will turn purple. This color is of little practical use as it is too hard to cut with a graver and too soft to use as a cutting tool itself.

600 degrees is the most commonly used color temperature, dark blue. At this point you will do most of your lathe work. Staffs are dark blue, barrell arbors, hairsprings, click springs, etc.

At 650 degrees the steel turns light blue. This color is of little practical purpose in your routine as a watchmaker, unless you are wanting something that will be easy to cut, such as threads.

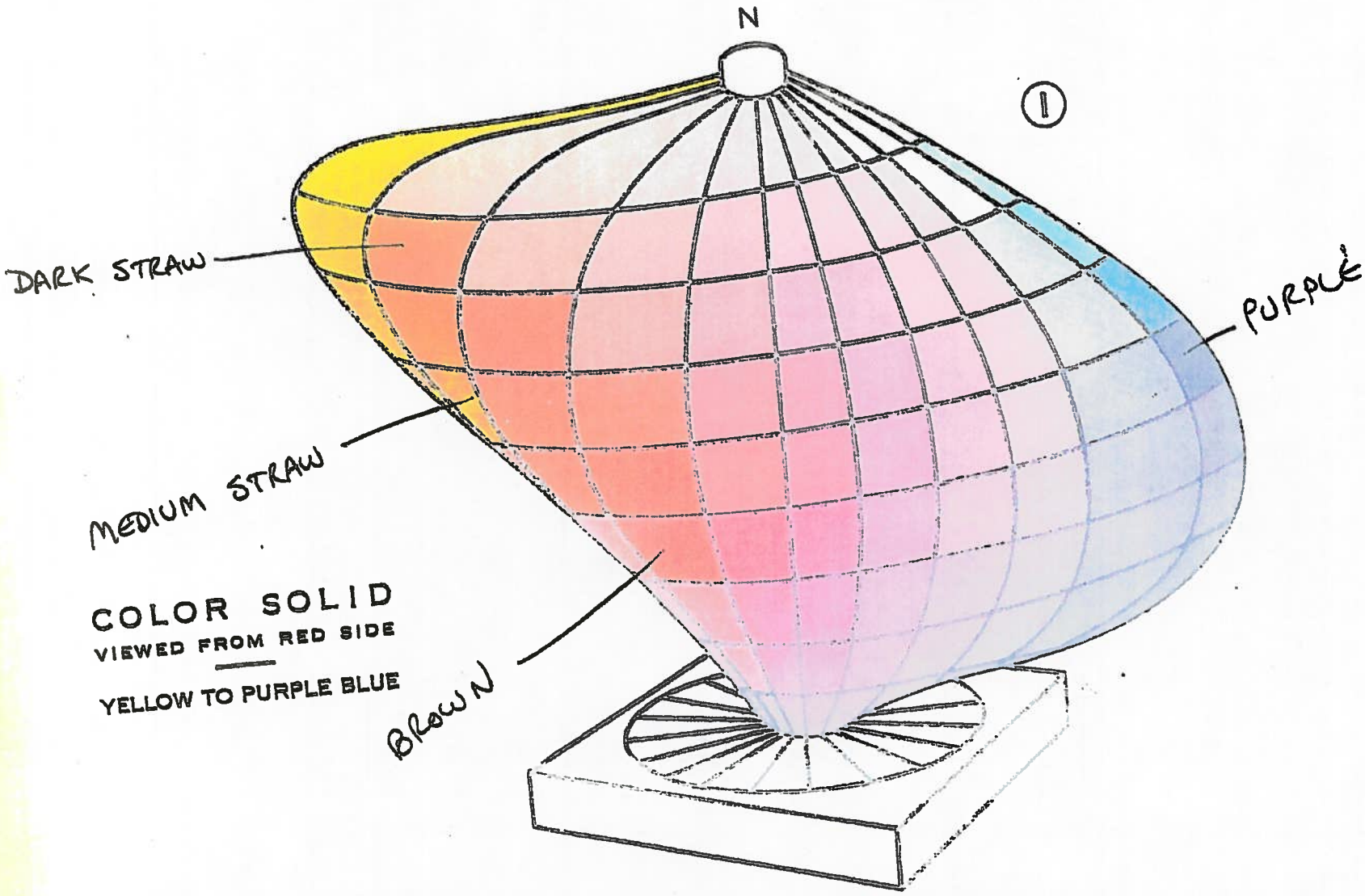
Now that we have gone all the way through the tempering process, let us explain what will happen if you make mistakes in the process.

As we stated before the colors that the steel turns are just a temperature gauge telling you how hot the steel has been at its MAXIMUM. This means the highest temperature that the steel has reached while you were tempering. If you heat the steel to a straw color but you were actually going for a dark blue, you cannot put the cooled steel (no matter what temperature the steel has cooled down to, whether a few degrees or all the way back) back into the flame trying to continue the process. Once the steel has cooled it must be polished off again and retempered. This meaning that you have not reached the desired color (temperature) so you may start over from a polished piece until you reach your desired color.

If you were going to a straw color but you heated the steel to a purple, you have gone too far and the steel must be rehardened and polished again. Then you may temper again. This simply means that you have reached too high a temperature (or too much color.)

Once a clear understanding of hardening and tempering has been reached, you will have a much easier time.

TEMPERING COLORS



COLOR SOLID
VIEWED FROM RED SIDE

YELLOW TO PURPLE BLUE

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